Ozone and NO_2 OSSEs on a Regional/Urban Scale for the GEO-CAPE Mission

EUMETSAT 2017 – METEOROLOGICAL SATELLITE CONFERENCE

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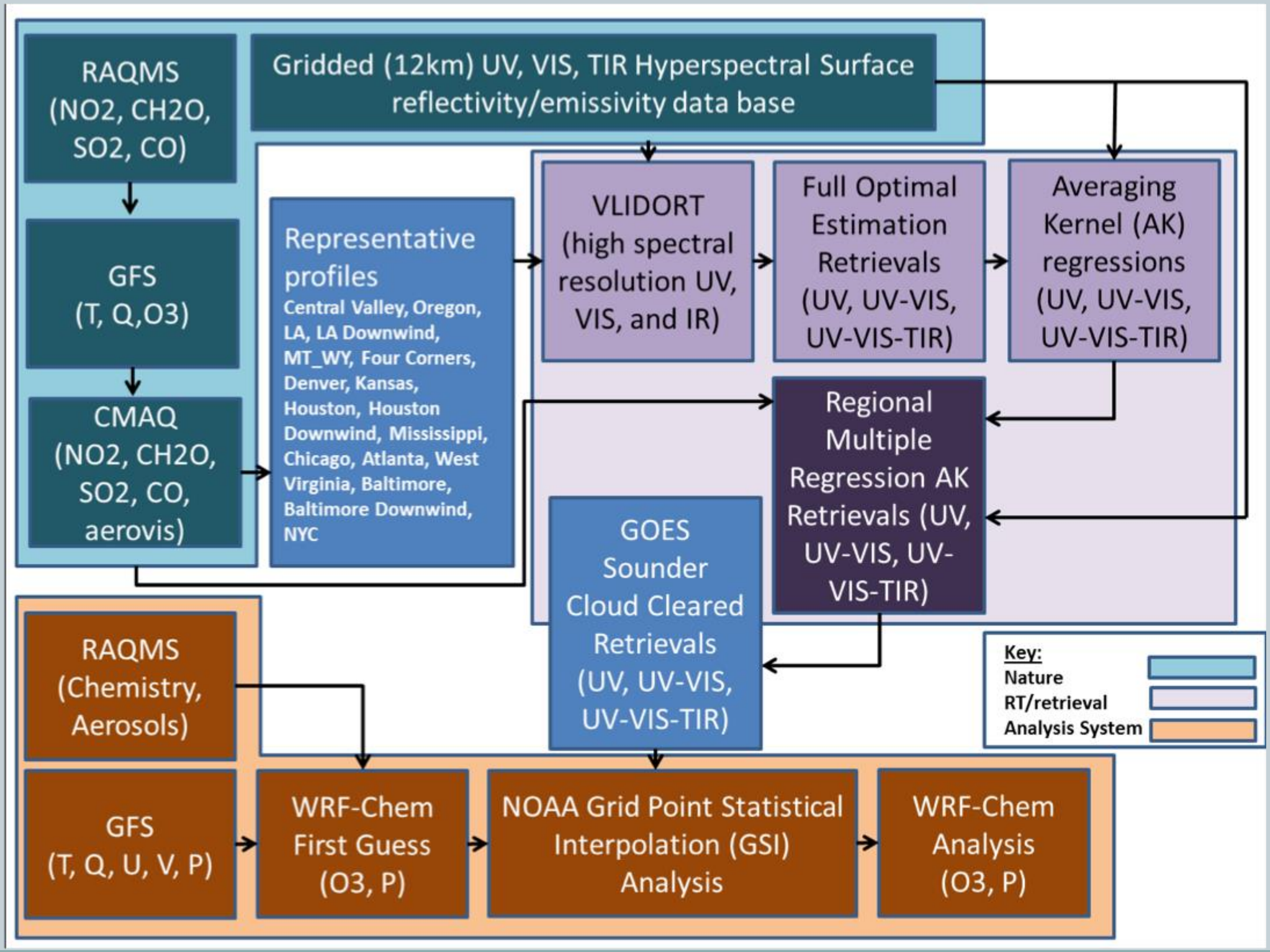
OSSE Flow Chart



Goals

- Utilize independent modeling systems for generation of Nature atmosphere and conducting assimilation impact experiments

- Account for realistic atmospheric variability, which requires evaluation of the nature runs with respect to observations

- Include realistic variability in the synthetic radiances, which requires using realistic albedos and emissivities

- Include realistic sensitivities, which requires generation of averaging kernels (AK) for each retrieval for use in assimilation studies

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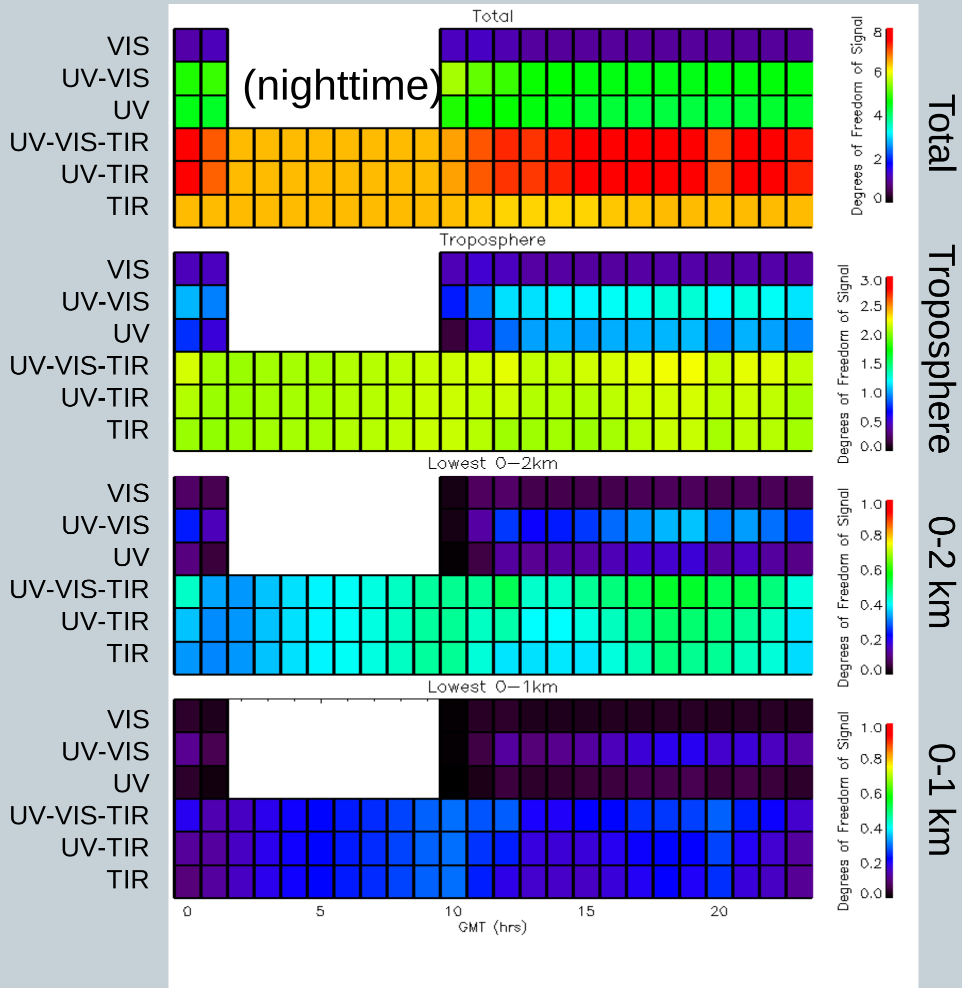
Forward Modeling for O_3

- Use a set of representative profiles from 17 sites (hourly, every 3rd day of July 2011)
- Perform full radiative transfer (using LIDORT)/Optimal Estimation
- Develop multiple regression estimate of the averaging kernels
- Use AK regressions for the full Nature atmosphere (CONUS, hourly, every day of July 2011) to generate the regional multiple regression AK retrievals

Multispectral O_3 Retrievals



Full Optimal Estimation Retrievals (UV, UV-VIS, UV-VIS-TIR)

Diurnally resolved Degrees of Freedom for Signal (DOFS) for different pressure ranges and spectral combinations for all GEOCAPE Regional OSSE sites (no VIS, UV, or UV/VIS retrievals between 02-09Z)

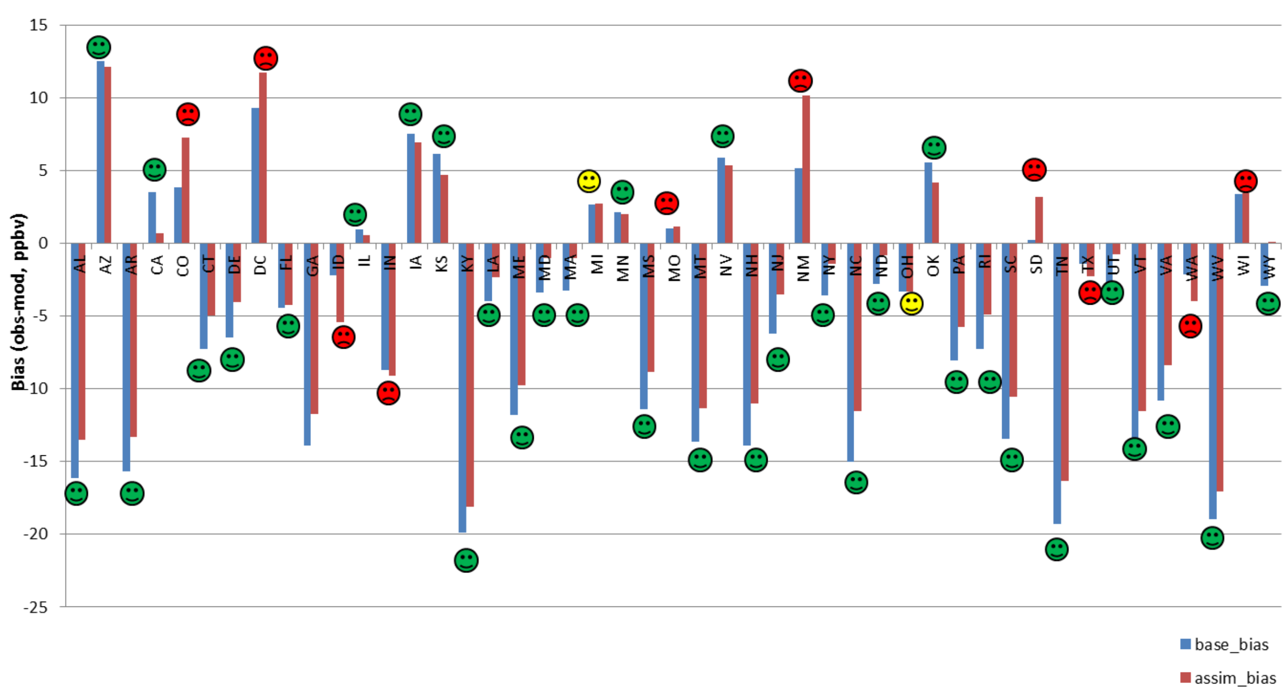
Note UV/VIS has the same spectral range and noise as TEMPO.

Impact of Assimilation: Overall Results

State AIRNow Bias Statistics GEOCAPE UVVISTIR OSSE July 1-5, 2011

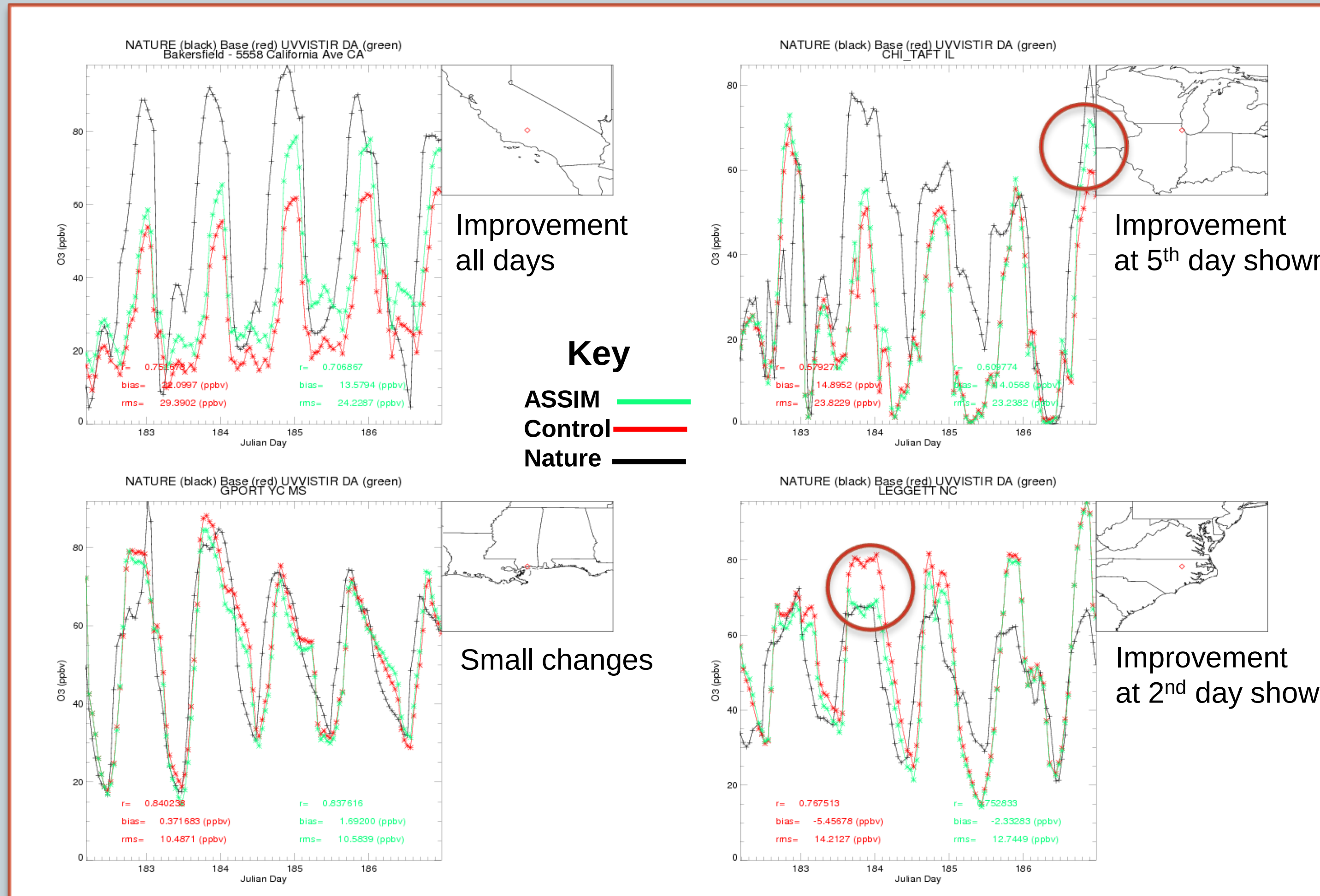
Nature-Control Nature-Assimilation

Assimilation Reduces Bias Assimilation Increases Bias Neutral results



74% (34 States) show reduced biases, 22% (10 States) show increased biases, and 4% (2 States) show neutral results at US EPA monitor locations when GEOCAPE UVVISTIR retrievals are assimilated

Impact of Assimilation: Selected Sites



Forward Modeling for NO_2 I

- O_3 simulations required 8 hrs per day (~15 hrs daylight) per station using 44 CPUs
- NO_2 has significantly larger spatial variability
- AK regression unlikely to produce good results
- Need to investigate fast forward modeling approaches

Forward Modeling for NO_2 II

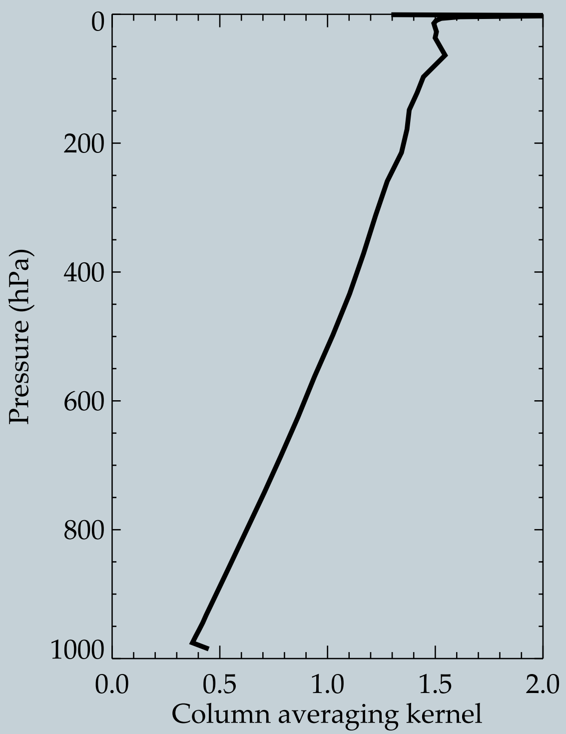
- Spectral region: 420–450 nm (TEMPO spectral range)

- Forward modeling approaches
  - LIDORT
  - Exact single scattering + two-stream multiple scattering (2S-ESS)
  - 2S-ESS + cross sections convolved to TEMPO spectral resolution (2S-ESS convolved)

2S-ESS Model

- Exact computation of the single scattering using all moments of the phase function
- Two-stream approximation for multiple scattering
- Accurate single scatter calculation captures forward peak of aerosol phase function
- Two-stream model completely analytic except for BVP (which is also optimized)
- Technique used, e.g., for water vapor retrievals over LA basin from CLARS measurements

NO_2 Retrievals: First Results



- Preliminary retrievals with TEMPO instrument characteristics meets GEOCAPE requirements for column precision

- We retrieve a profile scaling factor

- NO_2 has sensitivity in the lower troposphere and stratosphere

The Next Step in OSSEs

- In past OSSE experiments, one or two representative averaging kernels have been used to characterize sensitivity

- We find real satellite data sensitivity varies substantially, e.g. by aerosol optical depth, cloud cover, albedo, and viewing geometry

- Previous work by our group (H. Worden, 2013) characterized sensitivity using regression on a set of parameters, e.g. solar zenith angle

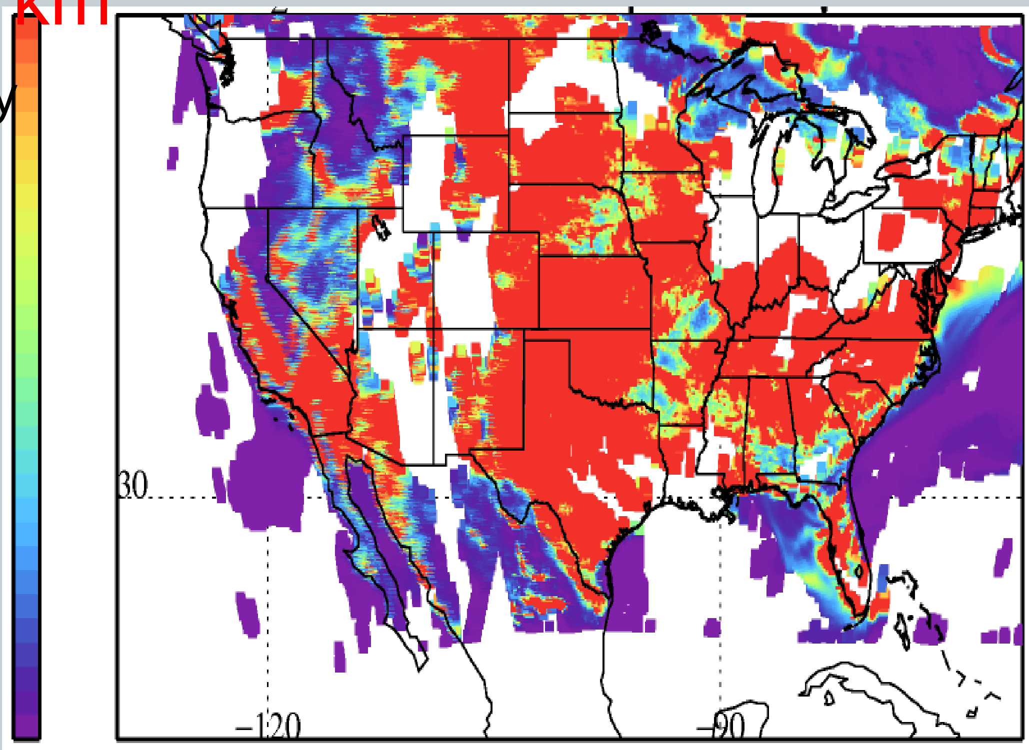
- Using a fast RT, we now estimate complete sensitivity during OSSE simulations

Real-time OSSE Estimates of Sensitivity

NO_2 sensitivity, surface to 2 km

Higher sensitivity

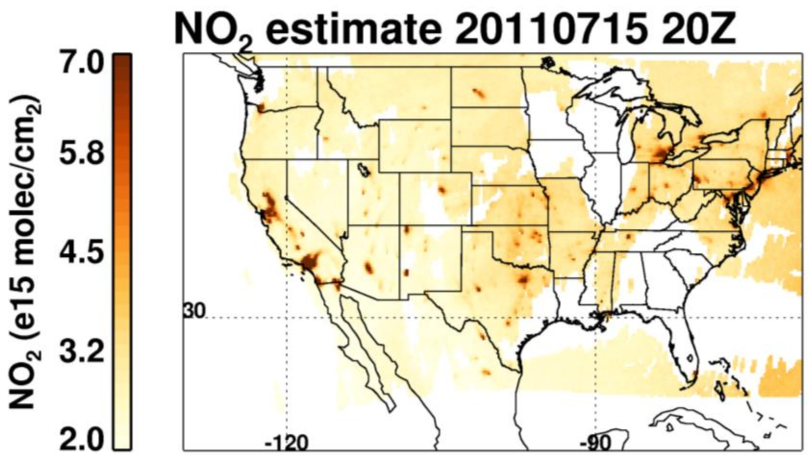
Lower sensitivity

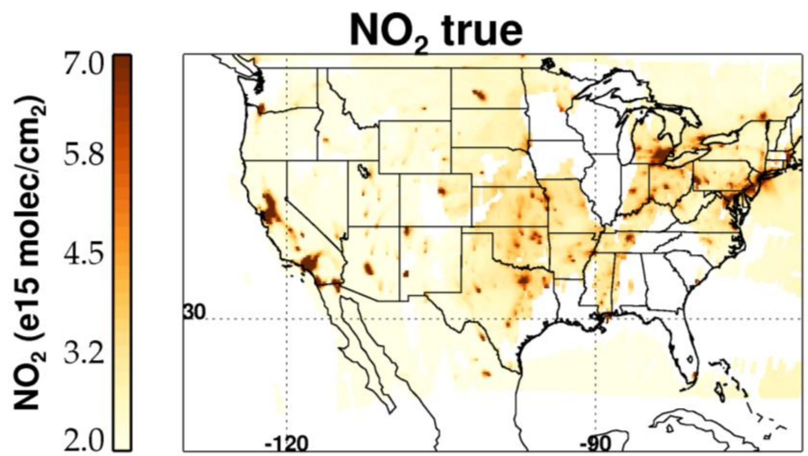


July 18, 2011 2 pm local time

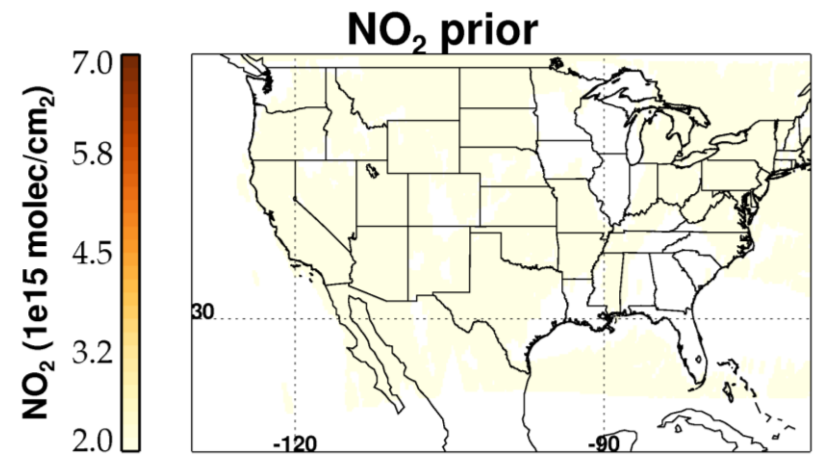
- Calculates Jacobians including aerosols and viewing geometry using fast RT system
- Better estimates what a satellite will actually see, which varies by location, time, and composition. Empty areas have thick cloud cover
- OSSEs will ingest results for better estimates of satellite performance

NO_2 Retrievals





- Simulated retrievals of the true state (left)
- Realistic variations in sensitivity allow more accurate evaluation of actual satellite performance

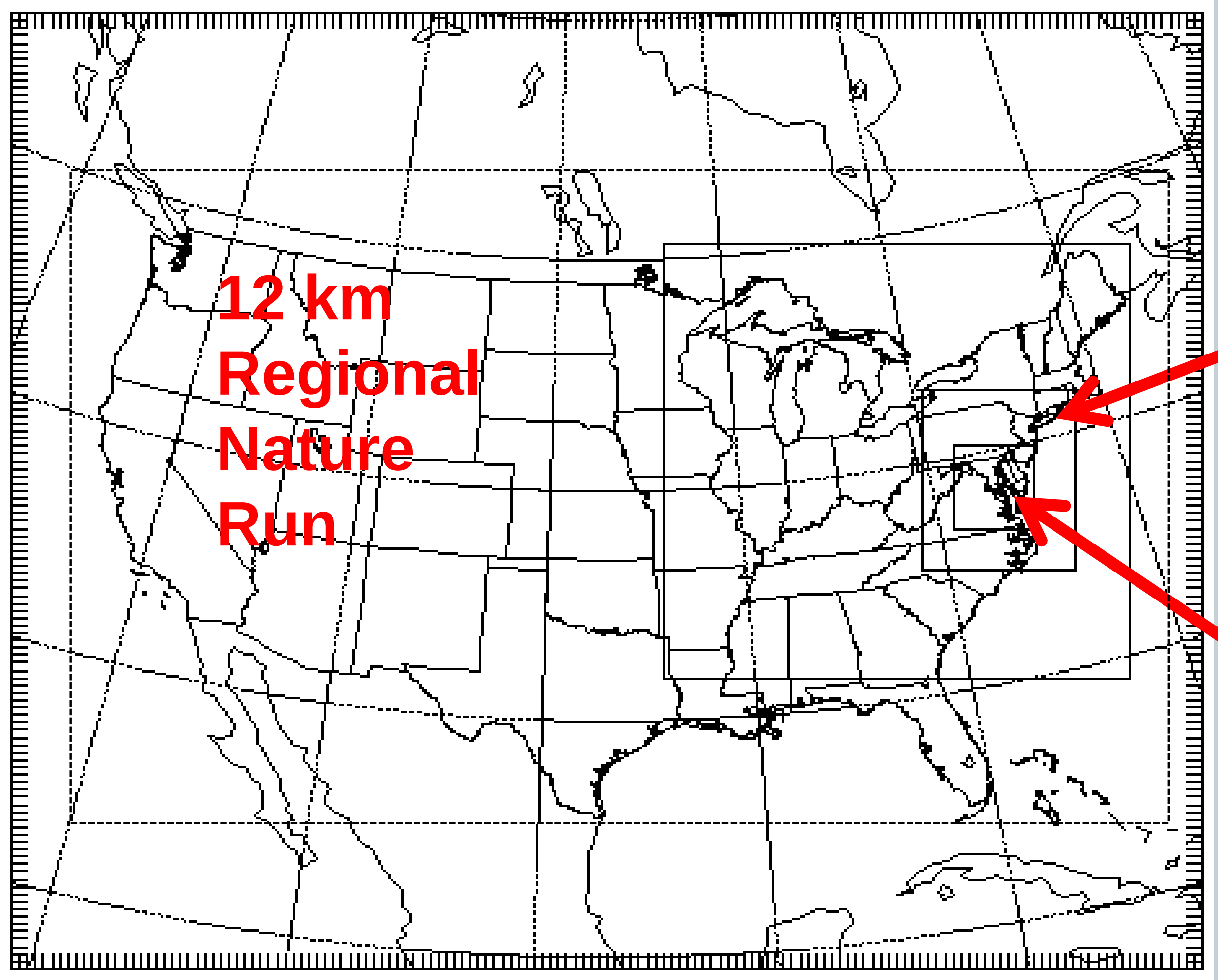


Conclusions

- Full UV-VIS-TIR retrievals showing positive impact on surface O_3
- O_3 Regional OSSE experiment shows reduction in bias when GEO-CAPE type measurements are assimilated
- Regional OSSE system showing realistic complexity
- NO_2 retrievals complete for 7/1/2011 – 7/31/2011
- Capability to obtain real time estimates of sensitivity developed

Backup Slides

Nature Run



Courtesy: K. Pickering/C. Loughner

Computational Time

- Computational time (one scenario):
  - LIDORT: 219 minutes
  - 2S-ESS: 295 seconds
  - 2S-ESS convolved: 78.5 seconds

- Computational time (one day, full domain):
  - LIDORT: > 8 years!
  - 2S-ESS: ~ 70 days
  - 2S-ESS convolved: 18 days

- With a 10x speed-up, we can perform calculations for one month for the entire domain in ~ two months

How do we get 10x speed-up?

- Optimize optical property initialization (mainly, aerosol phase function moments)
- Perform interpolation of aerosol phase function instead of moments
- Perform profile-independent operations (e.g. reading in of large aerosol optical property tables) only once
- Remove redundant copying of data between variables

How do we get 10x speed-up?

- Implement MPI interface to use multiple processors
- Compute solar geometry early and only perform further calculations for daytime scenarios
- Only consider cloud-free scenarios
- Balance the number of points on each processor to optimize processor utilization
- Only output data to netcdf file for clear and daytime scenarios